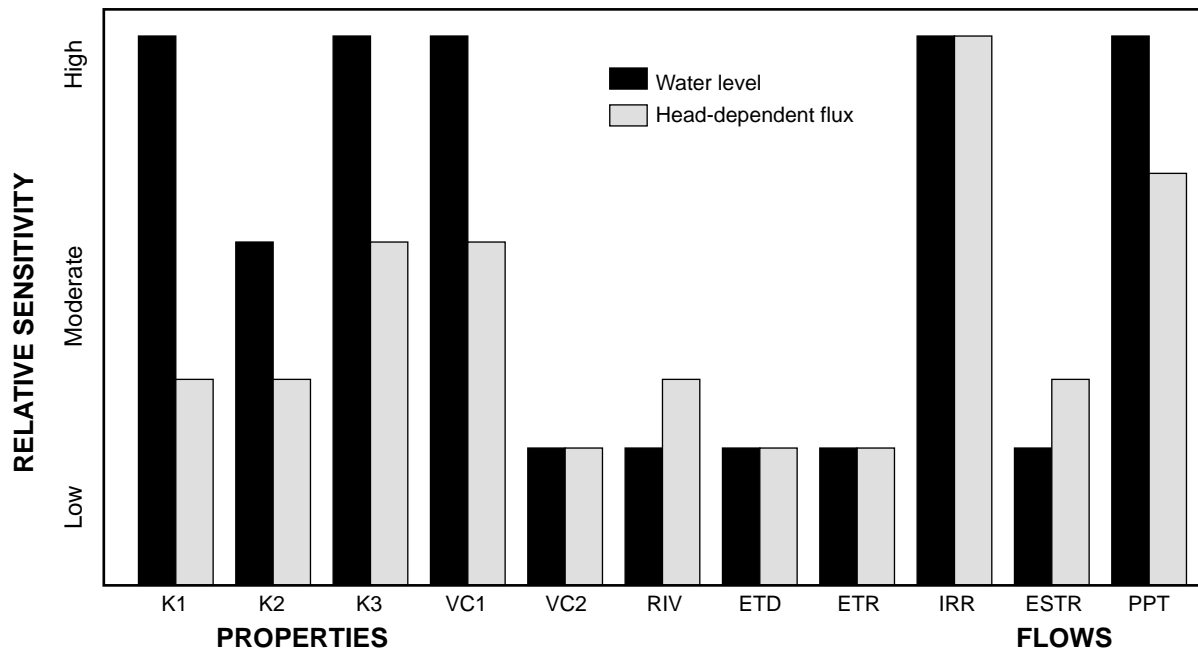


- |     |   |      |                                      |
|-----|---|------|--------------------------------------|
| K1  | Basin-fill horizontal hydraulic conductivity            | ETD  | Evapotranspiration extinction depth  |
| K2  | Alluvial-fan horizontal hydraulic conductivity          | ETR  | Maximum evapotranspiration rate      |
| K3  | Pine Valley monzonite horizontal hydraulic conductivity | IRR  | Recharge rate from irrigation        |
| VC1 | Basin-fill vertical leakance                            | ESTR | Recharge rate from ephemeral streams |
| VC2 | Alluvial-fan vertical leakance                          | PPT  | Recharge rate from precipitation     |
| RIV | Streambed conductance                                   |      |                                      |



**Figure 41.** Relative sensitivity of the baseline model representing the upper Ash Creek drainage ground-water flow system to uncertainty in selected properties and flows.

the basin's ground water, but only to visualize the interdependencies of hydrologic processes and the possible effects of climate change or human-caused change.

### Model Limitations

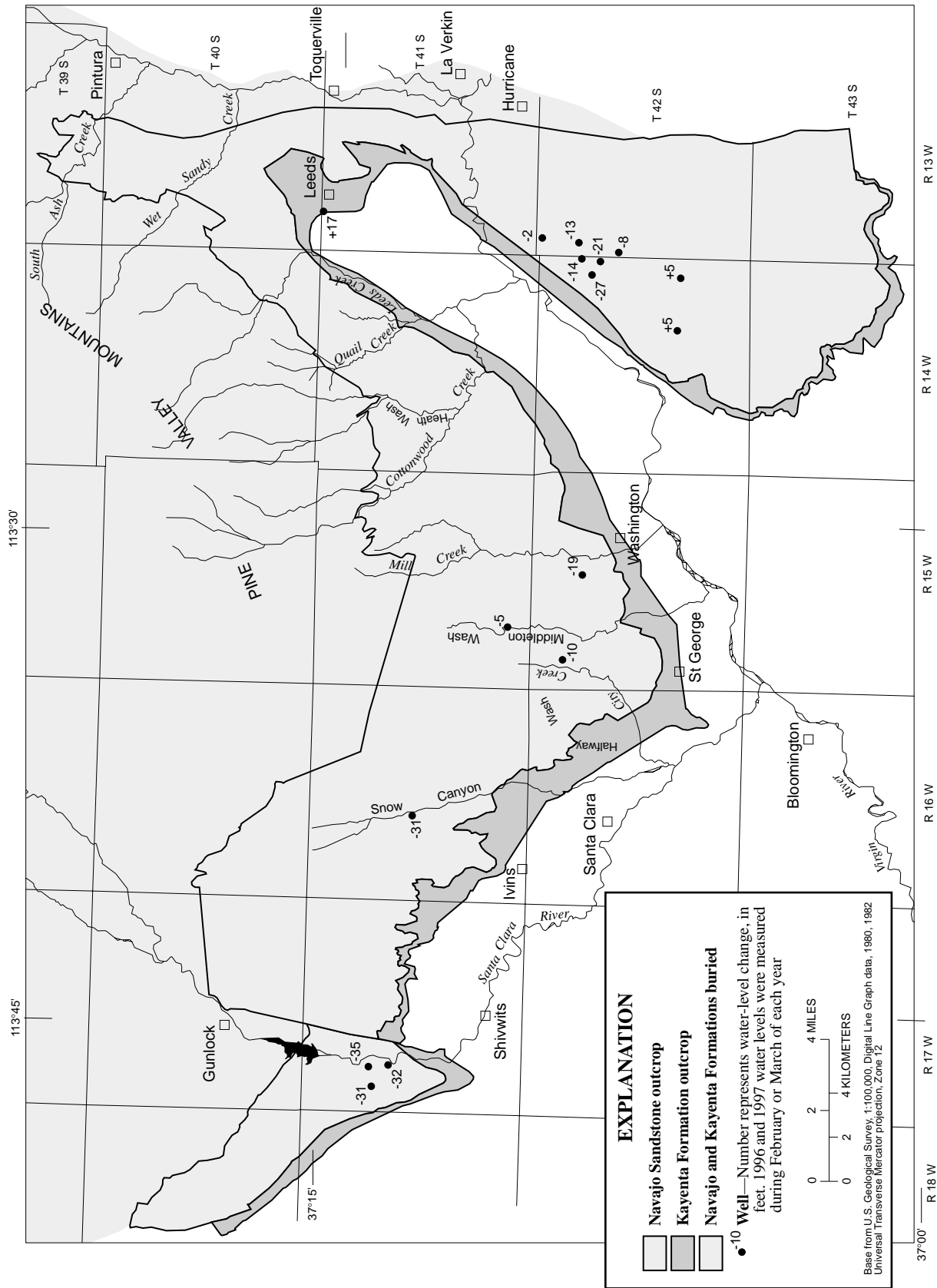
The limitations of the model have been implied in previous sections. The baseline simulation is considered to be the most reasonable representation for the upper Ash Creek ground-water system, but because the model has no storage component, it can only simulate the ultimate result of changes in stress on aquifer properties. Other representations may also be realistic, and thus the baseline simulation may need to be revised after additional hydrologic or geologic data about the system become available.

Alternate steady-state simulations could be devised to show the potential effect of (1) decrease in areal recharge because of drought, (2) removal of riparian vegetation, or (3) increased or decreased pumpage, but simulations such as these should not be used to

manage the water resources but rather to better understand interaction of hydrologic processes.

### Navajo and Kayenta Aquifer System

Because the Gunlock Fault completely offsets the Navajo Sandstone and Kayenta Formation outcrops (pl. 1), two separate ground-water flow models were developed for the main and Gunlock parts of the Navajo and Kayenta aquifers. The two computer models share similar aquifer properties and boundary conditions; for example, a shared no-flow boundary represents the Gunlock Fault. They were developed independently on the basis of the conceptual model ground-water budgets presented earlier (tables 15 and 16). Recharge to and discharge from the aquifers varies both seasonally and yearly as a result of both climatic changes and water use; however, there has generally been little overall water-level change at wells measured both in 1974 and as part of this study (fig. 42). Although at least 30 ft of water-level decline was measured at three of the Gunlock wells, those measurement were at productions



**Figure 42.** Water-level changes in the Navajo and Kayenta aquifers from 1974 to February/March 1996, 1997 in the central Virgin River basin study area, Utah.

wells and may reflect localized drawdown cones rather than regional declines. Also, these declines are small relative to the overall saturated thickness of the aquifer. Unfortunately, there are no long-term water-level data from the Navajo or Kayenta aquifer observation wells to show historical trends. Therefore, only steady-state models were developed for the main and Gunlock parts of the Navajo and Kayenta aquifers. The most recent year for which complete well discharge information was available was 1995. Water levels in wells were measured in 1996 and additional measurements were acquired in 1997 to fill in gaps. To evaluate the use of 1995 pumpage and 1996 to 1997 water levels for the steady-state model, February and March 1996 water levels were compared to measurements at 9 wells measured in February and March 1995 and 38 wells measured during June and July 1995. The average difference for the nine wells measured in February and March 1995 was a 1.6-ft decline in water levels, ranging from a rise of 2.5 ft to a decline of 12.8 ft. The average difference for the 38 wells measured in June and July 1996 was a 2.9-ft rise in water levels, ranging from a rise of 44.5 ft to a decline of 10.0 ft (Wilkowske and others, 1998, table 2). However, as stated earlier, most of the measured wells were production wells, so the larger changes (plus or minus more than 5 ft) were likely due to effects of seasonal pumping. Thus, while not ideal, the baseline simulation for the main Navajo-Kayenta model represents average conditions for the period 1995 to 1997. Although pumping did increase in 1996 and 1997, the 1995 withdrawals were an acceptable long-term average to try and represent in a steady-state simulation.

### **Main Part of the Navajo and Kayenta Aquifers**

The ground-water flow model developed for the main part of the Navajo and Kayenta aquifers includes the area west of the Hurricane Fault and east of the Gunlock Fault where the Navajo Sandstone and Kayenta Formation are exposed, as well as an area extending up to 4 mi north of the Navajo Sandstone/Carmel Formation contact, where the formations are buried. The model was developed as a simplified representation of a complicated and extensive aquifer system. The approach was to create a baseline model with which to test various alternative conceptualizations of aquifer properties.

### **Model Characteristics and Discretization**

The model is divided into 58 rows, 65 columns, and 2 layers with a total of 7,540 model cells (fig. 43). The model grid was designed to emphasize more detailed simulation of ground-water flow along the exposed outcrop part of the aquifers between the Hurricane Fault and Snow Canyon, where most hydrologic information is available. Therefore, the size of model cells ranges from about 2,000 ft by 2,000 ft along the center of the outcrop to about 2,000 ft by 5,000 ft along the northeast and the western parts of the simulation area. Layer 1 represents the Navajo aquifer and includes about 2,020 active cells simulating an area of about 330 mi<sup>2</sup>. Layer 2 represents the Kayenta aquifer and includes about 2,340 active cells simulating an area of about 390 mi<sup>2</sup>. The orientation of the grid was rotated clockwise about 10 degrees from true north so that the columns are parallel to the general orientation of predominant faulting and jointing.

The altitude of the base of layer 2 that represents the Kayenta aquifer is shown in figure 44. Generally this corresponds to altitudes 850 ft below the base of the Navajo Sandstone (Hurlow, 1998, pl. 5a), except where the base of the Kayenta aquifer is inferred to be lower than 1,850 ft below sea level in the northeast corner of the model. The saturated thickness of layer 1 ranges from 2,400 ft where the Navajo aquifer is confined by overlying formations towards the north, to less than 200 ft near its erosional extent. The saturated thickness of layer 2 ranges from 850 ft where the Kayenta aquifer is confined by overlying formations toward the north, to less than 200 ft near its erosional extent. A cross section of the model grid along column 20 shows the layer geometry used in the ground-water flow model (fig. 45).

### **Boundary Conditions**

The hydrologic boundaries that represent the main part of the Navajo and Kayenta aquifers include no-flow boundaries, specified-flux boundaries, and head-dependent (general-head) boundaries. No-flow boundaries representing the erosional and fault-controlled extent of the aquifers are fairly well defined. However, other boundaries, such as those representing flow to and from underlying, adjacent, and overlying formations, are not well understood. In general, these underlying and overlying formations are represented by no-flow boundaries except where hydrologic or geochemical evidence indicates that ground water may be crossing these boundaries. Where the aquifers are